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Title:
Porosimeter and methods of assessing porosity

Abstract:

A porosimeter comprises a gas supply 22 a gas pressure regulator 20 for automatically regulating the gas supply in accordance with pre-selected rate or pressure increase a sample holder 32 having an inlet connected to the regulator 20, a gas flow sensor 29 disposed to measure the gas flow between the regulator 20 and the sample holder 32, and a gas pressure sensor 28 for measuring the pressure of the gas supplied to the sample holder 32. Both pressure and flow-rate readings are taken directly from the respective sensors to an automatic recorder 30, or may be fed to, for example, an integrating computer. Separate pressure gauges 26, 27 and flow meters 36, 37 for calibration purposes and a bubble point detector 33 may also be provided.

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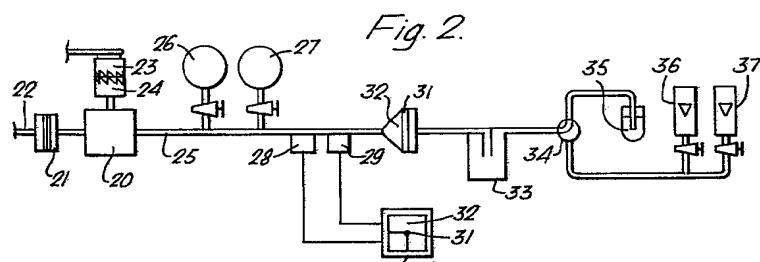
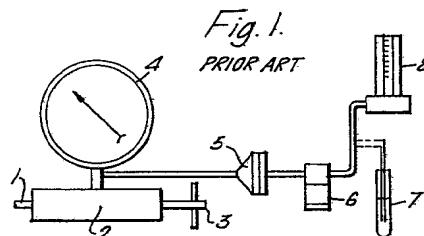
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G1S**(54) Porosimeter and methods of assessing porosity**

(57) A porosimeter comprises a gas supply 22 a gas pressure regulator 20 for automatically regulating the gas supply in accordance with pre-selected rate or pressure increase a sample holder 32 having an inlet connected to the regulator 20, a gas flow sensor 29 disposed to measure the gas flow between the regulator 20 and the sample holder 32, and a gas pressure sensor 28 for measuring the pressure of the gas supplied to the sample holder 32. Both pressure and flow-rate readings are taken directly from the respective sensors to an automatic recorder 30, or may, be fed to, for example, an integrating computer. Separate pressure guages 26, 27 and flow meters 36, 37 for calibration purposes and a bubble point detector 33 may also be provided.



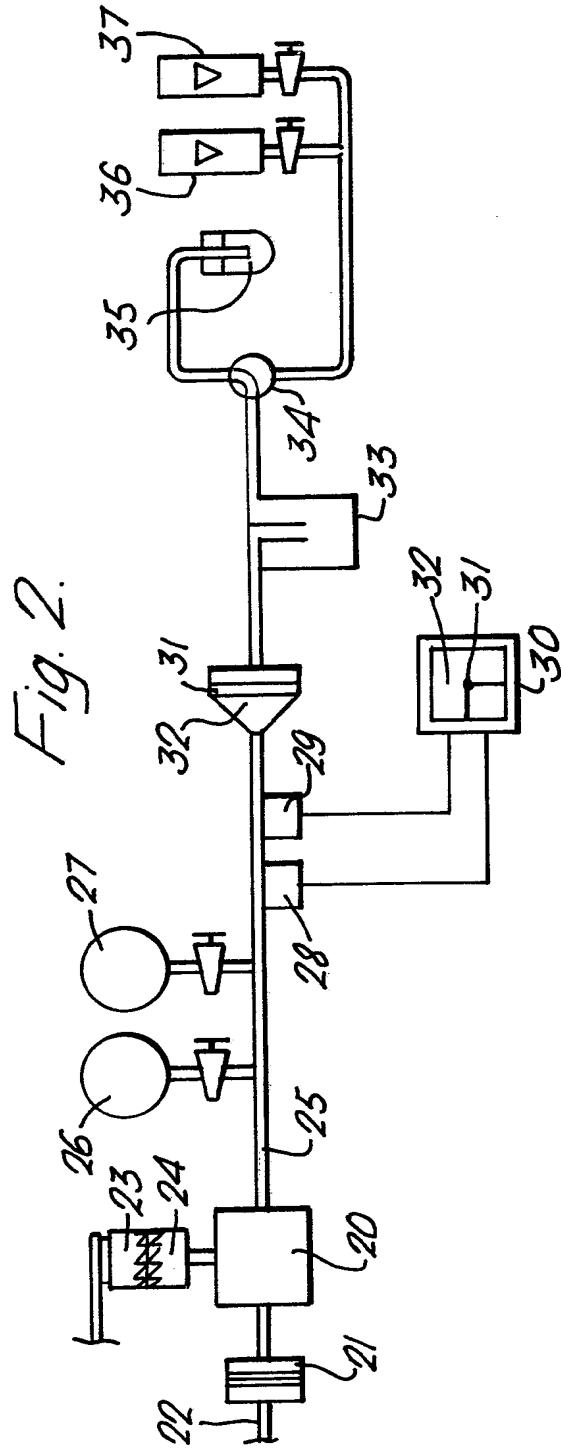
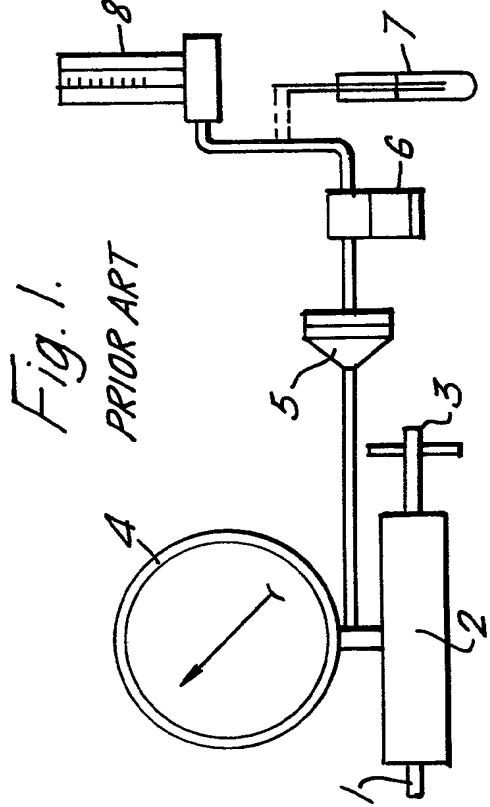
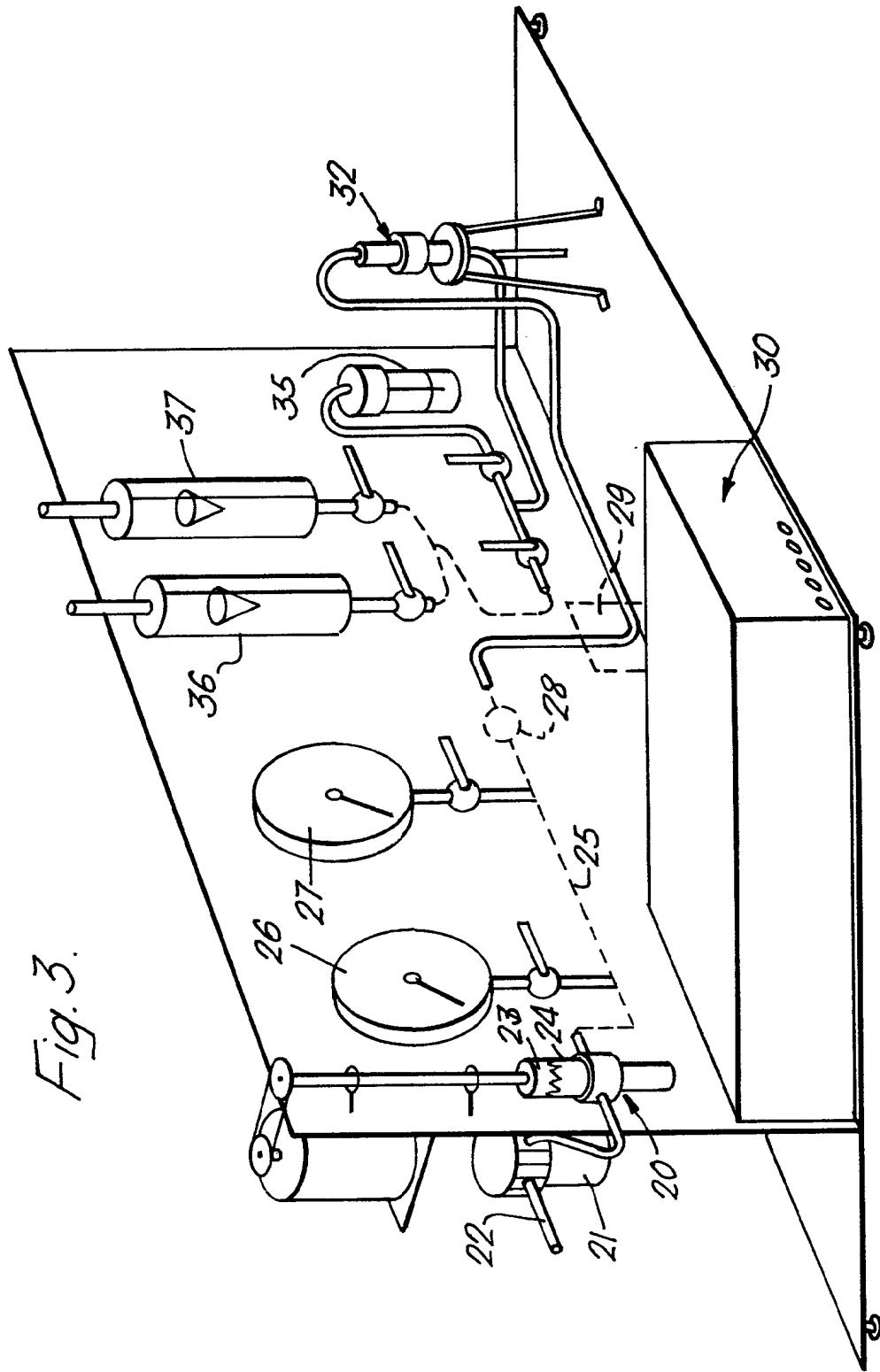


Fig. 3.



SPECIFICATION

Porosimeter and methods of assessing porosity

5 This invention relates to porosimeters and to methods of assessing porosity. A widely accepted standard apparatus and method for testing porosity is to be seen in ASTM F 316-80.

10 The object of the test is to gain information about the maximum pore size and the distribution of pore sizes in a porous material under test. The material is saturated with test liquid, held in a holder and subjected to progressively increasing pressure of a

15 test gas. The initial breakthrough of gas through the wet filter is noted by a bubble point detector and thereafter the relationship between pressure applied and flow through the material is observed using a pressure gauge and a rotameter downstream of the material and directly impelled by the flow of gas.

20 This test method is highly dependant on the manual skill and dexterity and the intellectual ability of the operator requiring as it does the simultaneous operation of the inlet pressure regulator and observation of the pressure gauge and the flow rate. Thereafter these 25 readings have to be converted manually by drawing graphs and these are then interpreted.

30 Despite these drawbacks this method is one of the accepted methods of testing porosity.

35 We have examined this and have in the present invention provided substantial improvements in various respects and in particular from the point of view of avoiding reliance upon manual skill.

40 In our apparatus and method we use a pressure gauge and flow meter only in an initial calibration which need not be done in the presence of the material to be tested. We further site our flow-rate sensor upstream of the material to be tested. In operation, we take both pressure and flow-rate readings directly 45 from the respective sensors to an automatic recorder which draws mechanically the output in the form of a graph, or may feed them to, for example, an integrating computer.

50 The siting of the flow-rate sensor upstream of the material to be tested is of great importance since that sensor works at a higher pressure on that side of the test material than it would on the downstream side and furthermore the positioning avoids any contamination of that sensor by the test liquid being 55 swept from the material. In the American Standard, a liquid trap is provided behind or downstream of the material but is not totally successful in preventing access of liquid into the subsequent stages of the apparatus which therefore can affect the accuracy of

60 We further improve the process by standardising the test liquid. Those mentioned in the American Standard are water, petroleum distillate, de-natured alcohol or mineral oil. We find that various characteristics of volatility, surface tension or reactivity will not allow any one of those materials to be used over a wide range of materials to be tested. We have selected a liquid which is of the widest possible applicability,

65 having very low surface tension and vapour pressure and in particular very low reactivity for the fibrous materials which are likely to form the materials under test. This material is known as Fluorinert (Registered Trade Mark) which is recommended by its makers Minnesota Mining and Manufacturing as a cooling

70 liquid for electronic components and devices. The preferred Fluorinert liquid is known as FC43 having a nominal boiling point of 174°C, a viscosity of 2.6 cs, a vapour pressure at 25°C of 0.3 mmHg and a surface tension at the same temperature of 16 dynes per cm.

75 Chemically, the liquid is a clear colourless perfluorcarbon fluid.

To relieve the operator further of the need for manual intervention we may provide a motorised drive for the inlet flow regulator whereby to achieve a 80 linear increase of pressure applied to the sample at a pre-selected rate which could be determined by the nature of the test material but will usually be independent of it, at least within a certain ranges of such pore sizes.

85 In the test method, it is preferred to take the wet curve first in a single sample holder and then repeat the run with the same sample in the same place to obtain the "dry" curve. In this way it is certain that an identical sample is giving the two curves (a comparison

90 between which gives the necessary data) and that no contamination or the like will enter the system as a result of its being opened up between the test. The ASTM assumes that the dry test will be taken first or else that two samples will be in the system.

95 The method of the invention may also include a calibration step performed before subjecting the sample to the test and which consists in running the gas through the system and first calibrating the pressure scale of the recorder against a pressure

100 gauge coupled into the line and then disconnecting the pressure input to the recorder and calibrating the flow-rate scale against a flow meter coupled into the line. The calibration may include the steps of returning the pressure and flow back to zero and recalibrating 105 the zero of the recorder, for as often as is necessary. However, neither the pressure gauge nor the flow meter will be used in normal operation during running of the tests.

In the accompanying drawings:

110 Fig. 1 is a diagrammatic view taken from ASTM F316-80 of the test apparatus as recommended and used until the present invention; and

Fig. 2 is a similar diagram of the apparatus according to the present invention; and

115 Fig. 3 is a sketch perspective view of the apparatus as mounted for use.

Fig. 1 shows a pressure source 1 with a pressure regulator 2 operated by a manual control 3. The pressure output from the regulator is seen on a gauge

120 4 and passes to a sample holder 5 between the two parts of which a sample is mounted, the sample having been moistened by any one of water, petroleum distillate, de-natured alcohol or mineral oil, all of a specified characteristics. Following the passage of 125 gas through the sample is an oil trap 6 and the duct is

initially coupled up after that to a so-called bubble point detector 7, wherein output if any being caused to bubble through liquid or to a rotameter 8 which is directly impelled by the flow of liquid. The initial 5 breakthrough of gas through the sample is noted by observation of the bubble point detector which sets a zero for a graph which is then drawn by manual correlation of the pressure gauge against the flow rate downstream of the sample as measured by the 10 rotameter 8.

In the present invention in contrast, as seen in Figs. 2 and 3, a pressure regulator 20 such as a Schrader regulator preceded by a filter 21 between it and a source of compressed gas 22, usually compressed air 15 is driven from a synchronous motor (not shown) through belting or other drive train and a ratchet clutch 23. It can be returned to zero by manual intervention on the part 24 of the clutch nearer to the regulator 20. Next in the line 25 leading from the 20 regulator are two pressure gauges 26, 27 which can be brought into communication with the line through respective valves. The pressure gauges are used for calibration only and they are sensitive in different ranges of pressure, only one being used for any given 25 calibration. Next in the line are transducers 28, 29 for pressure and flow-rate respectively. The pressure transducer may be of any known type but we have used one of the stressed metal film (also known as bonded foil strain gauge) type which gives an output 30 to an XY recorder 30 having a pen 31 drivable over graph paper 32 in either or both of the XY directions in accordance with respective inputs. The other input is derived from a flow-rate transducer 29 and we prefer to use a thermal mass flow meter since it is devoid of 35 moving parts. It can be seen that these devices are sensing both pressure and flow-rate in the ducting upstream of the sample 31 which is mounted in a standard holder 32 and which optionally may be followed by the standard liquid trap 33 and by a 40 two-way valve 34 which can divert flow either to a standard bubble point detector 35 or to standard flow meters 36, 37. Which of these two is connected to the line is selected by respective valves. The flow meters 36, 37 which are of the type which is impelled by the 45 flow of gas are used only in calibration of the device. The bubble point detector is however used to manually note the initial point of the breakthrough of the gas at which time a tick or similar mark is made manually on the graph paper in the recorder 30 as a safeguard 50 for extra accuracy in determining the origin of the curve which will be obtained.

In operation, calibration is first carried out without a sample in the holder. Gas is run through the system at a pressure similar to the maximum which will be 55 expected to be used in the following test. One or other of the pressure gauges 26, 27 is selected and the output from pressure transducer 28 only is fed to the recorder 30. The correlation between the position of the pen and the reading on the pressure gauges made 60 and if necessary the zeros are then calibrated, with recalibration at the high pressure and so on. Similarly, calibration of the flow-rate is carried out by taking the output from flow-rate transducer 29 only to the recorder and comparing the other reading of the pen 65 with the reading achieved by one of the two direct-

impelled flow meters 36 or 37 which may be appropriate to the expected maximum flow during the test. When calibration has been achieved the pressure gauges and the flow meters are switched out of the 70 system.

The valve 34 is switched over so that the bubble detector is in the circuit, a standard sample which may be for example a filter paper, a sintered micro-filter, a blotting paper, a geological material or any other 75 material of which it is wished to know the porosity, is saturated in Fluorinert FC43 and placed in the holder. The automatic drive 23 is coupled to the pressure regulator so there is an automatic and predetermined increase in the pressure applied to the sample and the 80 test is run, achieving a wet curve graph. The test is continued until that line becomes substantially straight, showing substantially complete drying of the sample. The pressure is then returned to zero and the run repeated with the sample still in the holder to 85 obtain the dry curve which is substantially a straight line. The two curves are plotted on the same piece of graph paper 32 automatically by the recorder 30 and are then removed for the necessary interpretation.

It is apparent that once the output signals have been 90 reduced to an electrical form as they are here, the results could be taken out to means such as a computer which would interpret them immediately in terms of for example pore size and distribution.

It can be seen that we have considerably improved 95 and rendered more reliable the method and apparatus proposed in the ASTM by removing very largely the reliance on manual dexterity and skill, by rearranging the circuitry shown in that ASTM in order to improve the performance and reliability of the whole and by 100 standardising our test liquid used to wet the material under test.

CLAIMS

1. A porosimeter comprising a gas supply, a gas pressure regulator for the gas supply, a sample holder 105 having an inlet and an outlet, said inlet being connected to the gas pressure regulator, a gas pressure sensor connected to the gas pressure regulator for measuring the pressure of gas supplied to the sample holder and a gas flow sensor wherein

110 the gas flow sensor is disposed to measure the gas flow between said gas pressure regulator and said sample holder.

2. A porosimeter according to Claim 1, wherein said gas regulator is controlled automatically to 115 regulate the pressure of the gas supplied to the sample holder inlet in a predetermined manner.

3. A porosimeter according to Claim 1 or Claim 2, wherein at least one gas pressure gauge is provided to calibrate the output from said gas pressure sensor, 120 said gas pressure gauge being capable of isolation from the flow of gas between said regulator and said sample holder inlet.

4. A porosimeter according to any one of the preceding Claims, wherein gas flow meters are provided to calibrate the output from said gas flow sensor said gas flow meters being capable of isolation from the flow of gas through said sample holder.

5. A porosimeter according to Claim 4, wherein said gas flow meters are connected to the outlet of 130 said sample holder.

6. A porosimeter according to any one of the preceding Claims, wherein the output from said gas flow and gas pressure sensors is processed electronically.

5 7. A porosimeter according to Claim 6, wherein the output from said sensors is recorded by a chart recorder.

8. A porosimeter according to Claim 6 or Claim 7, wherein the output from said sensors is electronically 10 processed to determine the pore size and distribution of samples tested.

9. A method of assessing porosity comprising first saturating a sample with fluid, placing the sample in the sample holder of a porosimeter according to any 15 one of the preceding Claims, increasing the pressure of gas supplied to the sample holder until the sample is substantially free of said liquid and then reducing the pressure to a lower value and increasing it again with the sample still in place.

20 10. A method of assessing porosity comprising allowing gas to flow through an apparatus according to Claims 3 and 4 in the absence of any sample, calibrating the output from said sensors using said pressure gauge and flow meter, thereafter isolating 25 said gauge and meter from the gas flow, reducing the gas flow to an initial value, placing a sample saturated in liquid in said sample holder, increasing the pressure of gas supplied to the sample holder until the sample is substantially free of said liquid and then reducing 30 the pressure to a lower value and increasing it again with the sample still in place.

11. A method according to Claim 9 or Claim 10, wherein the liquid used to saturate the sample is an inert perfluorocarbon fluid.

35 12. A method according to any one of Claims 9 to 11, wherein the liquid used has a boiling point of 174°C, a viscosity of 2.6cs, a vapour pressure at 25°C of a 0.3 mm Hg and a surface tension at 25°C of 16 dynes per cm.

40 13. A porosimeter substantially as herein described with reference to Figure 2.

14. A method of assessing porosity substantially as herein described with reference to Figure 2.

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